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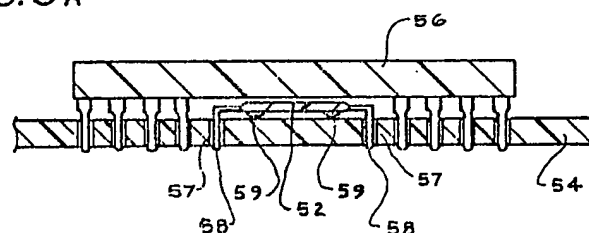
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## (54) Decoupling capacitor for pin grid array package

(57) High frequency noise is decoupled from power supplied to a Pin Grid Array (PGA) package (56), carrying an ic, by insertion of a decoupling capacitor (52) between the PGA package and printed circuit board (54). The decoupling capacitor (52) comprises a dielectric material sandwiched between a pair of conductors and having a plurality of leads (58) extending from each conductor. In accordance with the present invention, the decoupling capacitor is individually dimensioned and configured to fit under a PGA package and correspond to the power and ground pin configuration of that PGA package. The capacitor leads either enter holes in the pcb shared with leads of the PGA, enter non-shared holes or leads of the PGA pass through apertures in the capacitor leads.

The PGA comprises a pinned substrate carrying an i/c, and pins directly into the pcb or into a matching socket that mates with the pcb.

FIG. 9A



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FIG.1  
(PRIOR ART)

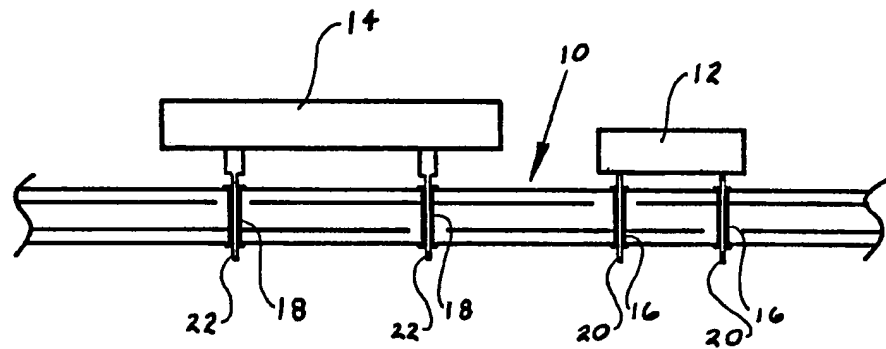


FIG.2  
(PRIOR ART)

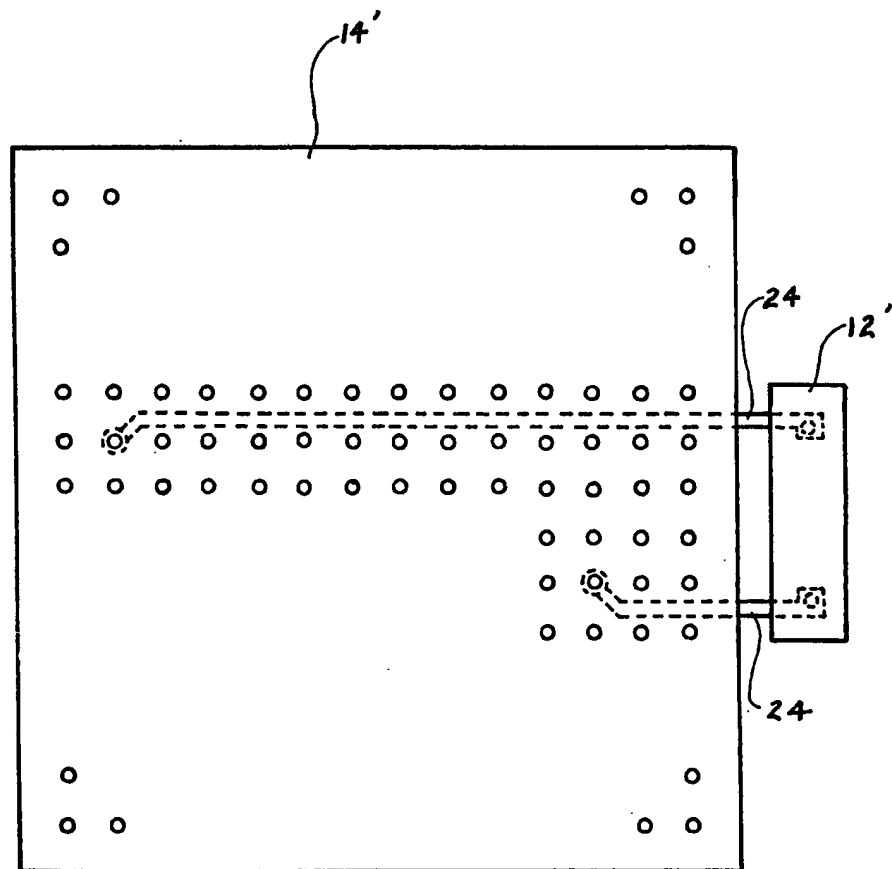


FIG. 3

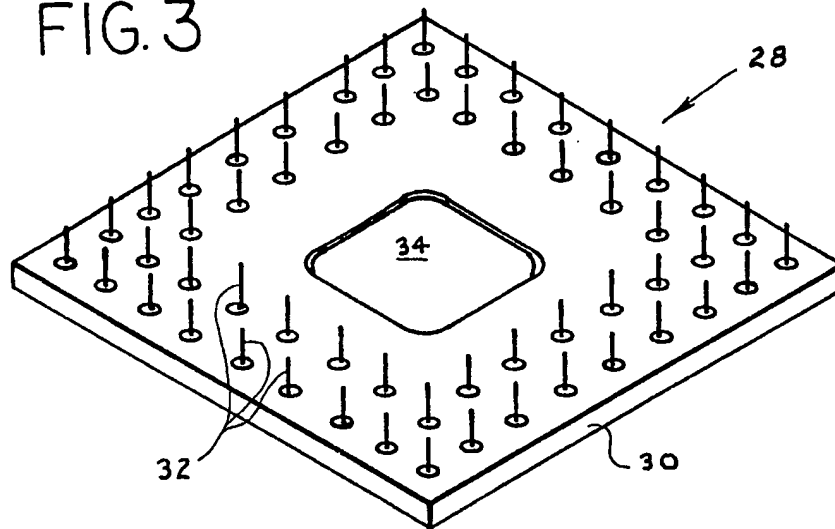
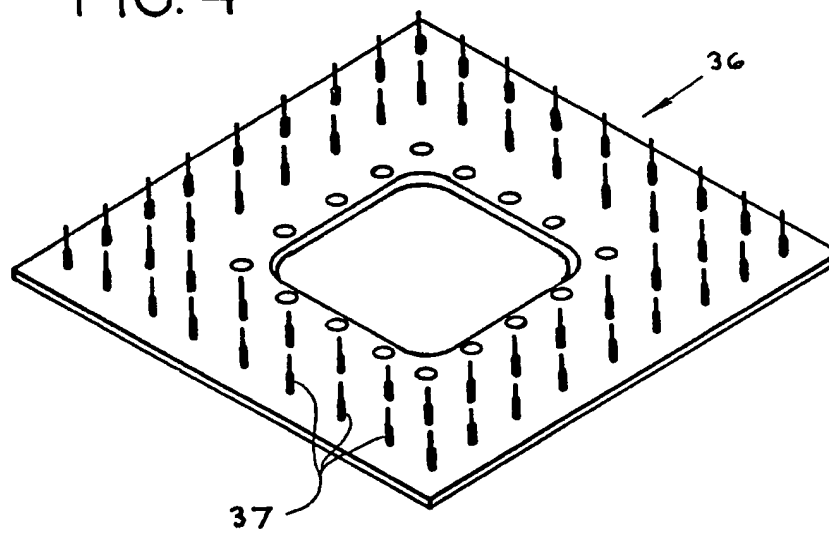
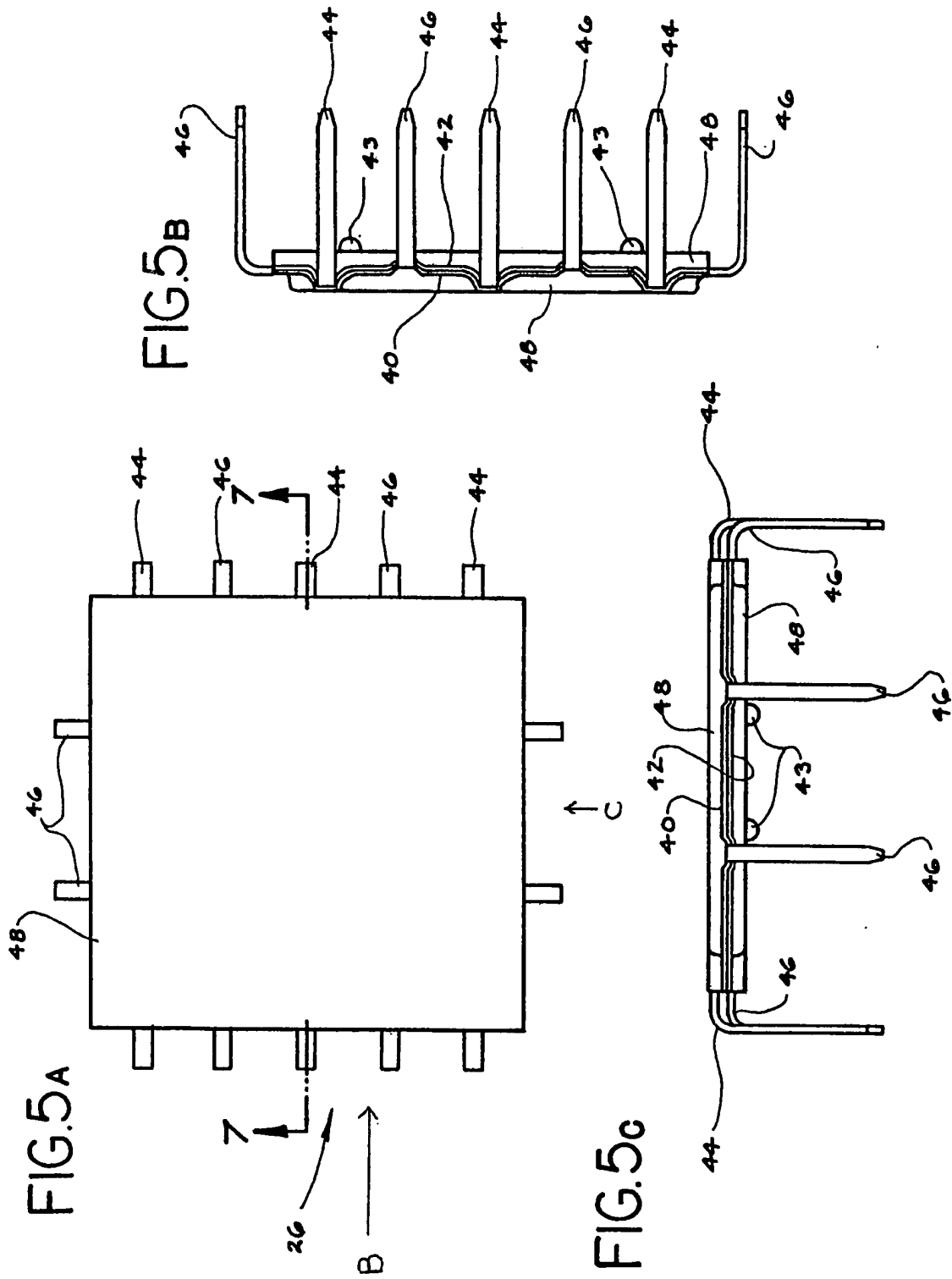
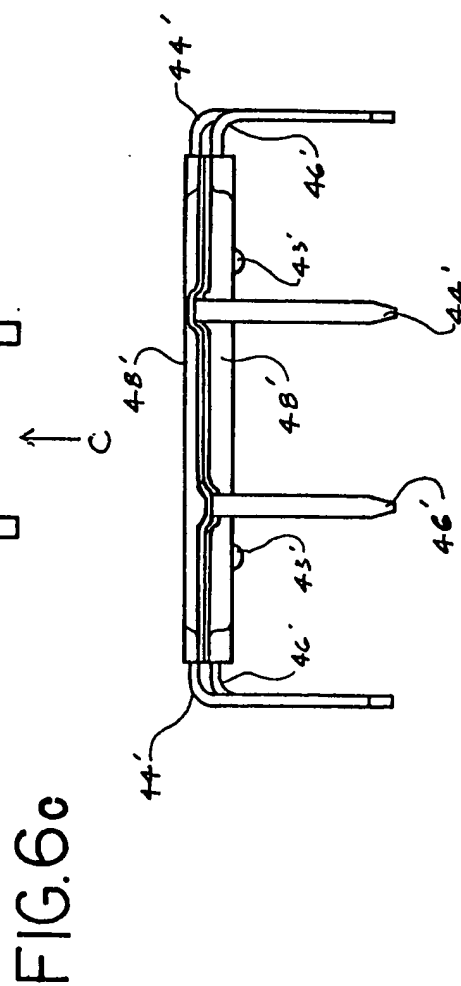
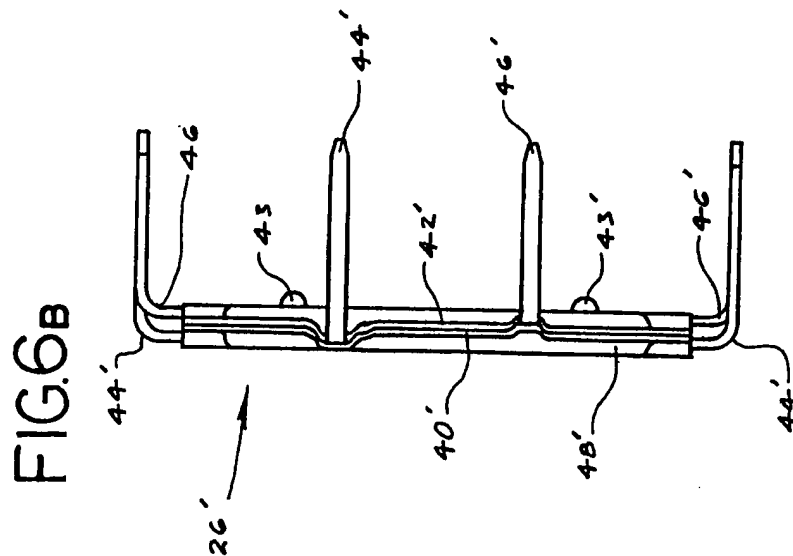
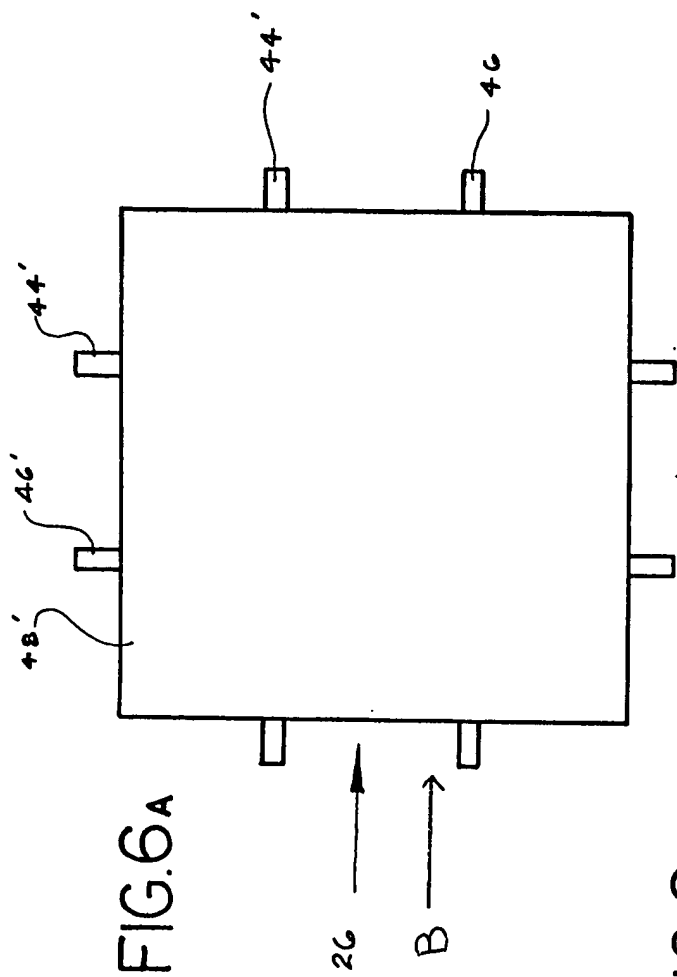


FIG. 4







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FIG.7

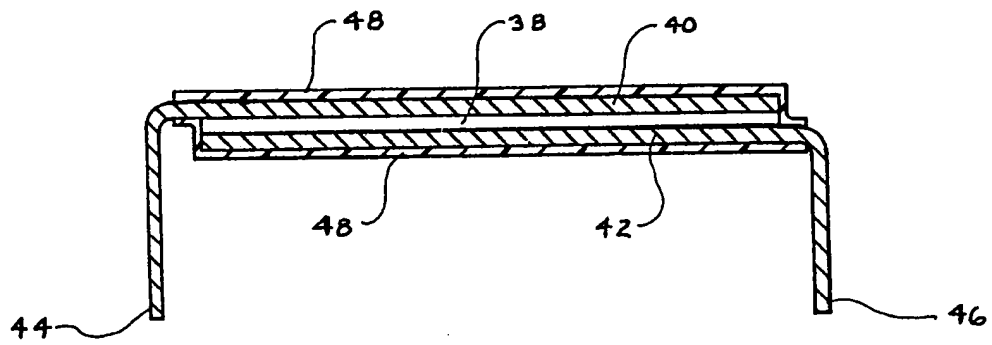


FIG. 8A

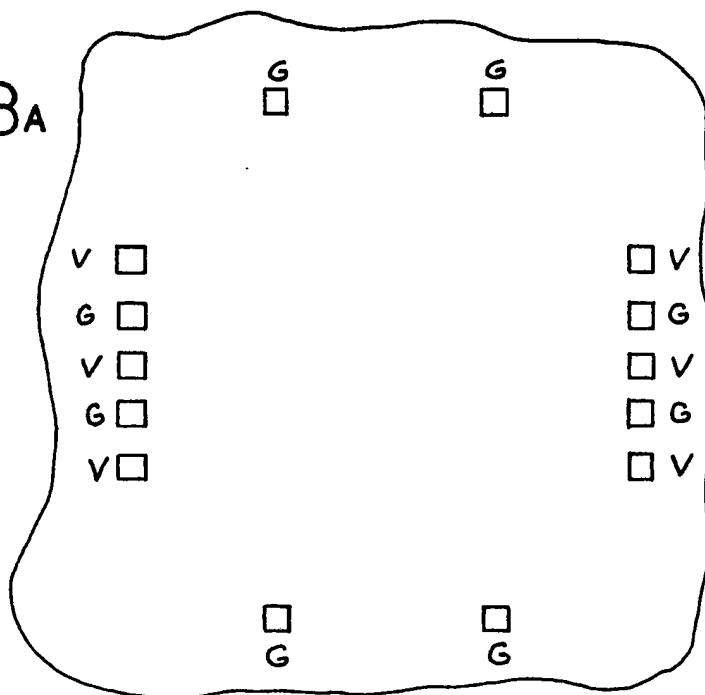


FIG. 8B

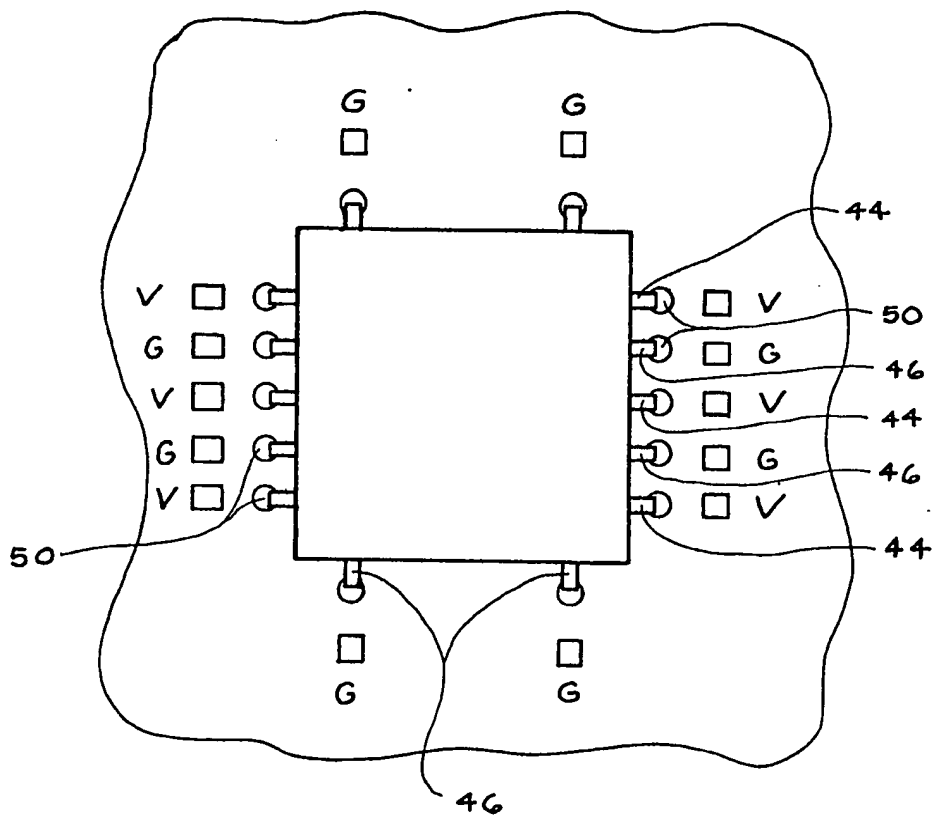


FIG.9B

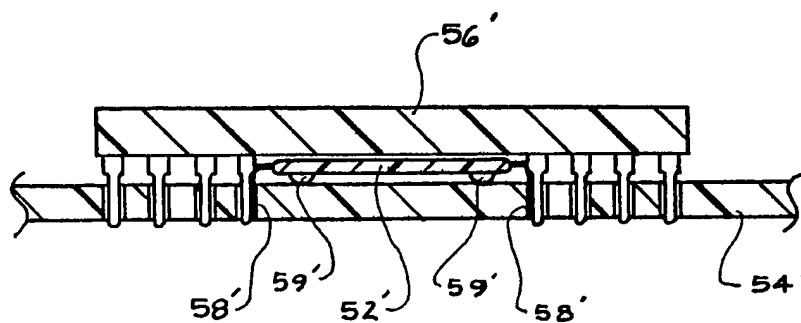


FIG.9A

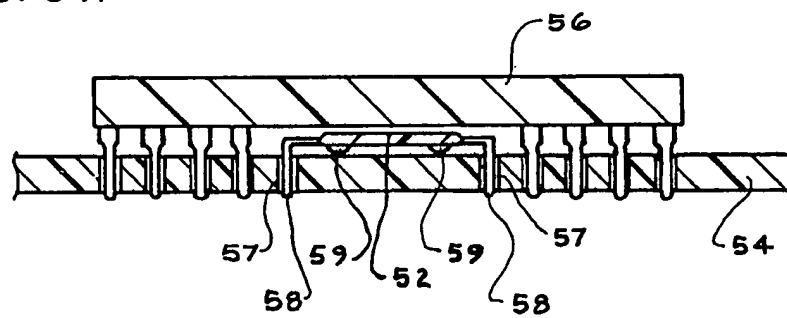




FIG. 10A

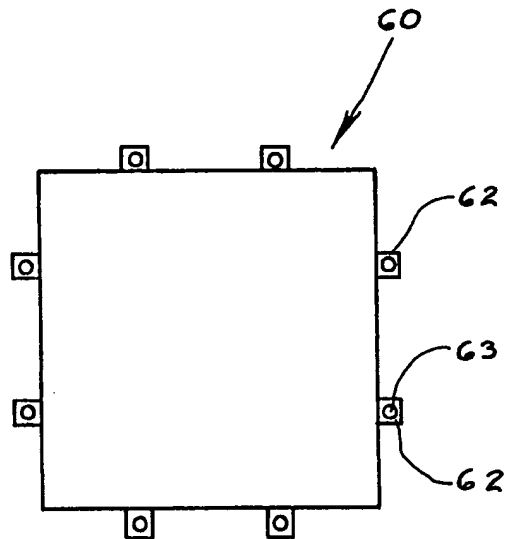
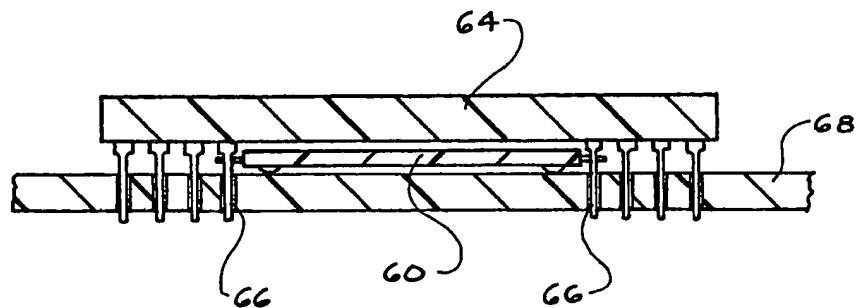


FIG. 10B



## SPECIFICATION

**Decoupling capacitor for pin grid array package**

5 This invention relates to the field of decoupling capacitors for integrated circuits. More particularly, this invention relates to novel and improved decoupling capacitors especially suitable for use in conjunction with Pin Grid Array (PGA) type integrated circuit packages.

10 It is well known in the field of microelectronics that high frequency operation, particularly the switching of integrated circuits, can result in transient energy being coupled into the power supply circuit. Generally, the prevention of the coupling of undesired high frequency noise or interference into the power supply for an integrated circuit is accomplished by connecting a decoupling capacitor between the power and ground leads of the IC. One connection scheme utilizes a capacitor which is mounted on a multilayer printed circuit board, outside the integrated circuit with plated through-holes used to connect the capacitor to the internal power and ground planes, which in turn make contact with the power supply connection leads of the integrated circuit. A less preferred method (in terms of higher inductance) is to interconnect the decoupling capacitor and integrated circuit power and ground leads via traces on either a multilayer or double sided printed circuit board.

The above two decoupling techniques suffer from several deficiencies. The most serious of these deficiencies resides in the fact that the circuits, including the capacitors, become highly inductive at high frequencies as a consequence of the shape and length of the leads and interconnection traces between the discrete capacitor and the integrated circuit which it decouples. In fact, the inductance of the leads and printed circuit board traces may be sufficiently high to nullify the high frequency effect of the capacitor in the circuit. A second serious deficiency resides in the spatial inefficiency incident to employing a capacitor adjacent to the integrated circuit. The space requirements, i.e., real estate, of the decoupling capacitor and the interconnection traces on the printed circuit board adversely affect the optimum component packaging density which can be achieved on the board.

In an effort to overcome the above-discussed deficiencies associated with the use of decoupling capacitors mounted on a printed circuit board, a decoupling capacitor which is adapted to be mounted underneath a conventional dual-in-line circuit has been proposed in DE-A1-3323472. The decoupling capacitor of that prior application is a thin rectangular chip of ceramic material which is metallized on opposite sides and has two electrically active leads from the metallized coatings on opposite sides of the chip at two points adjacent a pair of diagonally opposed corners of the rectangular shaped ceramic chip. The capacitor may also contain two or more electrically inactive dummy leads. The two active (and dummy) leads are bent downwardly, and the decoupling capacitor assembly is encapsulated in a film of nonconductive material. In accord-

ance with the teachings of that prior application, the decoupling capacitor is dimensioned so as to be received in the space between the two rows of leads extending from a conventional dual-in-line integrated circuit. The two electrically active leads from the decoupling capacitor are plugged into a printed circuit board, with these leads from the capacitor being inserted into the printed circuit through-holes to which the ground power supply conductors are connected. The associated integrated circuit or other electronic component is then positioned over the capacitor and inserted into the board such that the power supply leads of the integrated circuit or other component will be positioned in the same through-holes of the printed circuit board in which the two electrically active capacitor leads have been inserted.

While suitable for its intended purposes, the known decoupling capacitor is not particularly adapted to be used in conjunction with Pin Grid Array (PGA) type integrated circuit packages. PGA packaging is becoming a commonly used IC packaging technology. As with conventional dual-in-line packages, PGA packages require similar decoupling across the power and ground leads. However, decoupling capacitors of the type disclosed in the prior patent application have a structure and configuration which preclude their usage in conjunction with the distinctive configuration of well known PGA packages.

In accordance with the present invention, there is provided a decoupling capacitor for use with a Pin Grid Array package, the Pin Grid Array package having an array of pins extending from one side of a substrate, the center of the one side having no pins extending therefrom and defining a chip cavity area, at least some of the pins surrounding the chip cavity area being power and ground pins, the capacitor including a flat dielectric body having a pair of opposed surfaces, a first conductor on one of said opposed surfaces of said dielectric body defining a ground conductor, a second conductor on the other of the said opposed surfaces, of said dielectric body defining a power conductor, a plurality of first leads in electrical contact with said first conductor and extending outwardly therefrom, a plurality of second leads in electrical contact with said second conductor and extending outwardly therefrom, the power or ground configuration of said first and second leads corresponding to the power or ground configuration of said Pin Grid Array pins, an insulating material encapsulating said dielectric body and conductors, said leads extending through said insulating film and said encapsulated assembly being dimensioned to fit within said center of said Pin Grid Array package. In accordance with the present invention, the flat decoupling capacitor adapted for mounting directly under a Pin Grid Array package is provided which will result in a lower decoupling loop, thus providing a more effective decoupling scheme. The capacitor of the present invention also contributes to a savings in board space, i.e., takes up less "real estate" on the printed circuit board, by resting entirely under the PGA package.

A decoupling capacitor for use in conjunction with

PGA packages in accordance with the present invention comprises a dielectric material, sandwiched between a pair of conductors. A plurality of leads are provided along the periphery of each conductor.

5 These leads extend outwardly a short distance generally in the plane of the metal conductors to which they are attached and are then bent downwardly so as to extend in a direction which is perpendicular to the planes of the conductors. The entire assembly, with the exception of the plural transversely extending lead portions, may then be encapsulated within a suitable non-conductive material.

The decoupling capacitor assembly of the present invention is specifically sized and configured so as to be received in the space directly below the integrated circuit chip and between the downwardly extending pins of a PGA package. It is well known that PGA packages have many different types of pin configurations. Accordingly, the present invention has flexible lead locations and multiple pins from each voltage level of the PGA so as to be tailored to a particular PGA package.

The above-discussed and other advantages of the present invention will be apparent to and understood by those skilled in the art from the following detailed description and drawings.

Referring now to the drawings, wherein like elements are numbered alike in the several Figures:

30 *Figure 1* is a side view of a Pin Grid Array package connected to a multilayer ceramic capacitor via plated through-holes and internal planes in accordance with the prior art;

*Figure 2* is a plan view of a Pin Grid Array package connected to a multilayer ceramic capacitor via printed circuit traces in accordance with the prior art;

*Figure 3* is a perspective view of a Pin Grid Array package;

*Figure 4* is a plan view of a Pin Grid Array socket;

40 *Figure 5A* is a plan view of a decoupling capacitor for use in conjunction with a Pin Grid Array package in accordance with the present invention;

*Figure 5B* is a side elevation viewed in the direction of arrow B in *Figure 5A*;

45 *Figure 5C* is a side elevation viewed in the direction of arrow C in *Figure 5A*;

*Figure 6A* is a plan view, similar to *Figure 5A*, of another embodiment of a decoupling capacitor in accordance with the present invention;

50 *Figure 6B* is a side elevation viewed in the direction of arrow B in *Figure 6A*;

*Figure 6C* is a side elevation viewed in the direction of arrow C in *Figure 6A*;

*Figure 7* is a cross-sectional elevation view along the line 7-7 of *Figure 5A*;

*Figure 8A* is a pin designation of the inside pins of the Pin Grid Array package similar to the Pin Grid Array package of *Figure 3*;

60 *Figure 8B* is a pin designation of the decoupling capacitor of *Figure 5A* connected to the inner perimeter of pins of the Pin Grid Array package of *Figure 3A*;

*Figure 9A* is a cross-sectional elevation view of the decoupling capacitor of the present invention mounted underneath a Pin Grid Array package on a

circuit board;

70 *Figure 9B* is a cross-sectional elevation view, similar to *Figure 9A*, of an alternative method of mounting the decoupling capacitor of the present invention;

*Figure 10A* is a plan view of another embodiment of a decoupling capacitor in accordance with the present invention;

75 *Figure 10B* is a cross-sectional elevation view of the decoupling capacitor of *Figure 10A* mounted underneath a Pin Grid Array package on a circuit board.

Referring first to prior art *Figure 1*, a multilayer printed circuit board 10 is shown having a multilayer ceramic capacitor 12 and a Pin Grid Array (PGA) package 14 mounted thereon. Capacitor 12 is mounted outside PGA package 14 and plated through-holes 16 and 18 are used to connect the capacitor leads 20 to the power and ground leads 22 of the PGA package 14. Prior art *Figure 2* shows a less effective decoupling scheme wherein printed circuit traces 24 are used to connect power and ground leads of the PGA package 14' with the decoupling capacitor 12'.

90 As discussed earlier, the prior art decoupling schemes of *Figures 1* and *2* both suffer from serious deficiencies and drawbacks including high inductance in the leads and printed circuit board traces (especially in the *Figure 2* assembly) as well as inefficient use of board real estate which adversely affects component packaging density.

These important problems are overcome by the decoupling capacitor of the present invention which is dimensioned and configured specifically to be used in conjunction with Pin Grid Array packages. Referring first to *Figures 3* and *4*, a typical PGA package is shown generally at 28. Pin Grid Array package such as that shown in *Figures 3* and *4* are well known to those skilled in the art and comprise a square or rectangular base portion 30 having a plurality of pins 32 in an array or pattern extending therefrom. The pins may be of several types including signal pins, power and ground pins and alignment pins. Generally, the power and ground pins 32 of PGA package 28 are located about the inner periphery of the pin array (i.e., the inner rings of pins) and surround the center area 34. The center of the PGA package has no pins extending therefrom and is defined as the chip cavity area 34. Chip cavity area 34 receives an integrated circuit chip (not shown) to complete the PGA package. It is well known that the pin configuration and overall sizing of PGA packages may differ significantly from one part to the next depending upon the particular electronic requirements. It will be appreciated then, that while a PGA package having two concentric rows of pins is shown in *Figure 3*, a PGA package may have (and usually does have) more concentric rows of pins.

125 The PGA package 28 of *Figure 3* may be mounted (i.e., soldered) either directly on a printed circuit board or may be preliminary mounted in a socket 36 (*Figure 4*) prior to circuit board mounting. Socket 36 includes a plurality of pin sockets 37 which correspond to pins 32 and are adapted for receiving pins 32

therein.

It will be appreciated that the decoupling capacitor of the present invention is dimensioned and configured to be mounted under a PGA package (such as the one shown in Figure 3) in the chip cavity area either under a socket or directly under a soldered package as will be discussed in more detail below with reference to Figures 9A and 9B.

Turning now to Figures 5A-5C and 7, a decoupling capacitor in accordance with the present invention is shown generally at 26. Decoupling capacitor 26 is comprised of a dielectric material or dielectric chip 38 (see Figure 7) sandwiched between a pair of metal conductors 40 and 42. Each conductor 40, 42 has a plurality of leads 44 and 46 which are connected thereto and extend outwardly therefrom. The leads extend outwardly a short distance and then are bent downwardly so as to extend in a direction which is perpendicular to the planes of the conductors. The entire assembly, with the exception of the plural transversely extending lead portions are then encapsulated within a suitable non-conductive material 48. The encapsulation may be laminated insulation, a molded process or any other applicable method. The conductors 40, 42 may vary in thickness and in alloy content. The dielectric 38 may be comprised of any suitable dielectric material, preferably ceramic. Preferably, a pair of stand offs 43 are formed in encapsulation 48 to permit cleaning between the decoupling capacitor and circuit board.

The decoupling capacitor 26 of Figures 5A-5C include a total of fourteen leads 44, 46, six leads 44 being connected to one conductor 40 (voltage conductor), and eight leads 46 being connected to the other conductor 42 (ground conductor). However, it will be appreciated that Figures 5A-5C describe only one particular lead configuration which is suitable for one (or more) particular Pin Grid Array package and its unique power pin configuration. As mentioned earlier, the dimensions and pin configurations of PGA packages can differ significantly from package to package. Accordingly, an important feature of the decoupling capacitor of the present invention is that it may be easily tailored to be used in conjunction with any PGA package. For example, in Figures 6A-6C an alternative embodiment of a decoupling capacitor is shown at 26'. Capacitor 26' has the same parallel plate capacitor structure of a dielectric material sandwiched between two conductors as does capacitor 26. However, unlike Figures 5A-5C, the decoupling capacitor 26' of Figures 6A-6C includes a total of eight leads 44' and 46', four leads being connected to each conductor. Also, the outer dimensions of capacitor 26' may differ from the outer dimension of capacitor 26 depending upon the dimensions of the PGA package which is being used in conjunction therewith.

As mentioned, the lead configuration of the decoupling capacitor of the present invention will be adapted to suit the particular needs of a selected PGA package power pin configuration. In Figure 8A, a pin designation of the power pin configuration of a PGA package for use with the decoupling capacitor 26 of Figures 5A-5C is shown. Figure 8A is thus representative of the pin configuration along the

inner perimeter of pins of a PGA package such as the one described in Figure 3. Each box in Figure 8A represents a pin while the symbol "G" or "V" indicates whether the pin is power (voltage) or ground. Referring now to Figure 8B, a decoupling capacitor 26 of Figures 5A-5C has now schematically been provided to the printed circuit board via additional holes 50. Each lead 44, 46 from capacitor 26 is matched with a corresponding voltage or ground pin from the PGA package to provide decoupling thereto. It should be understood that eight leads 46 from capacitor 26 are connected to a ground conductor while the other six leads 44 are connected to the voltage conductor in the capacitor.

Referring now to Figure 9A, the decoupling capacitor 52 of the present invention is shown mounted on a printed circuit board 54 underneath a PGA package 56. PGA package 56 is similar to PGA package 28 of Figure 3, however, the PGA package 28 of Figure 3 has been flipped over so that the pins extend downwardly through the printed circuit board 54. As discussed, enough space in the chip cavity area of the PGA package remains for the decoupling capacitor 52 of the present invention to be placed thereunder. In Figure 9A, separate holes 57 have been provided in the circuit board 54 for receiving leads 58 therein. It will be appreciated that the leads of capacitor 52 and pins of PGA package 56 are connected either by plated through-holes in a multi-layer circuit board or by relatively short traces. As mentioned, the present invention is preferably provided with stand offs 59 which permit cleaning between the circuit board 54 and decoupling capacitor 52.

Turning now to Figure 9B, an alternative method of mounting the decoupling capacitor of the present invention is shown. In Figure 9B, the leads of capacitor 52' and pins of PGA package 56' share a circuit board hole. This method of mounting may be preferable to that shown in Figure 9A as no additional holes need be provided to the printed circuit board 54'.

An alternative lead configuration to that discussed heretofore is shown in the decoupling capacitor 60 of Figures 10A and 10B. Decoupling capacitor 60 has the same structure as those described earlier except that leads 62 are formed as extended tabs, each tab having an opening 63 therethrough for receiving the pin 66 of a PGA package 64. Decoupling capacitor 60 may thus be mounted on pins 66 of PGA package 64 prior to installation on printed circuit board 68 which may ease assembly and permit the use of automatic insertion equipment.

The decoupling capacitor for use in conjunction with Pin Grid Array packages of the present invention has many features and advantages not found in the prior art. For example, by mounting a flat decoupling capacitor directly under a PGA package, the result will be lower inductance decoupling loop, thus providing a more effective decoupling scheme. This alleviates many of the problems associated with the high inductance of the prior art decoupling schemes of Figures 1 and 2.

The present invention also permits a reduction in the amount of circuit board "real estate" occupied

by the prior art decoupling devices of Figures 1 and 2. The need to save circuit board space to permit higher component mounting density is presently an important concern to those skilled in the art of electronic circuit design. Accordingly, the present invention addresses this problem by employing the novel mounting of decoupling capacitors underneath PGA packages.

## 10 CLAIMS

1. A decoupling capacitor for use with a Pin Grid Array package, the Pin Grid Array package having an array of pins extending from one side of a substrate, the center of the one side having no pins extending therefrom and defining a chip cavity area, at least some of the pins surrounding the chip cavity area being power and ground pins, the capacitor including a flat dielectric body having a pair of opposed surfaces, a first conductor on one of said opposed surfaces of said dielectric body defining a ground conductor, a second conductor on the other of the said opposed surfaces of said dielectric body defining a power conductor, a plurality of first leads in electrical contact with said first conductor and extending outwardly therefrom, a plurality of second leads in electrical contact with said second conductor and extending outwardly therefrom, the power or ground configuration of said first and second leads corresponding to the power or ground configuration of said Pin Grid Array pins, an insulating material encapsulating said dielectric body and conductors, said leads extending through said insulating film and said encapsulated assembly being dimensioned to fit within said center of said Pin Grid Array package.

2. A capacitor as claimed in claim 1, wherein said encapsulated assembly is substantially rectangular.

3. A capacitor as claimed in claim 2, wherein said encapsulated assembly is substantially square.

4. A capacitor as claimed in claim 1, wherein said leads extend outwardly and downwardly perpendicular to said conductors.

5. A capacitor as claimed in claim 1, wherein each of said leads comprise a tab having an opening therethrough for receiving one of said pins from said Pin Grid Array package.

6. A capacitor as claimed in claim 1, including stand off means provided on said encapsulating material of said decoupling capacitor.

7. An electronic subassembly comprising a Pin Grid Array package, said Pin Grid Array package having an array of pins extending from one side of a substrate, the center of said one side having no pins extending therefrom and defining a chip cavity area, at least some of the pins surrounding the chip cavity area being power and ground pins, a circuit board, said circuit board having first spaced holes receiving said Pin Grid Array package pins, and a decoupling capacitor, said decoupling capacitor being positioned in the center of said Pin Grid Array package and thus being interposed between said chip cavity area of said pin Grid Array package and said circuit board, said capacitor means comprising a flat dielectric body having a pair of opposed surfaces, a first

conductor on one of said opposed surface of said dielectric body defining a ground conductor, a second conductor on the other of the said opposed surfaces of said dielectric body defining a power conductor, a plurality of first leads in electrical contact with said first conductor and extending outwardly therefrom, a plurality of second leads in electrical contact with said second conductor and extending outwardly therefrom, the power or ground configuration of said first and second leads corresponding to the power or ground configuration of said Pin Grid Array pins, an insulating material encapsulating said dielectric body and conductors, said leads extending through said insulating material and said encapsulated assembly being dimensioned to fit within said center of said Pin Grid Array package.

8. A subassembly as claimed in claim 7, wherein said encapsulated assembly is substantially rectangular.

9. A subassembly as claimed in claim 8, wherein said encapsulated assembly is substantially square.

10. A subassembly as claimed in claim 7, wherein said leads extend outwardly and downwardly perpendicular to said conductors.

11. A subassembly as claimed in claim 7, wherein each of said leads comprise a tab having an opening therethrough for receiving one of said pins from said Pin Grid Array package.

12. A subassembly as claimed in claim 7, including stand off means provided on said insulating material of said decoupling capacitor.

13. A subassembly as claimed in claim 12, wherein said stand off means define a space between said decoupling capacitor and said circuit board.

14. A subassembly as claimed in claim 7, including second space holes in said circuit board for receiving said power and ground leads of said decoupling capacitor.

15. A subassembly as claimed in claim 7, wherein said power and ground leads of said decoupling capacitor are in the same holes as the corresponding power and ground pins of said Pin Grid Array.

16. A decoupling capacitor substantially as hereinbefore described and as illustrated in the accompanying drawings.

17. An electronic subassembly substantially as hereinbefore described and as illustrated in the accompanying drawings.